ADDITIONAL SPECIMENS OF EARLY PERMIAN BRACHIOPODS FROM THE CALLYTHARRA FORMATION, CARNARVON BASIN, WESTERN AUSTRALIA: NEW MORPHOLOGICAL DATA

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New fossil brachiopod material from the Sakmarian (Sterlitamakian) part of the Callytharra Formation, Carnarvon Basin, Western Australia, is reviewed and described. New taxa described are the new species *Neospirifer (Quadrospira) preplicatus* Hogeboom and the new genus *Wooramella* Archbold. New records of species from the Callytharra Formation are *Tornquistia* sp. cf. *T. subquadratus* Archbold (1990) and *Taeniothaerus irwinensis* Coleman (1957). Additional morphological details are described for the species *Callytharrella callytharrensis* (Prendergast 1943).

Key words: Permian, Brachiopoda, Western Australia, Callytharra Formation, new taxa.

EARLY PERMIAN marine faunas and stratigraphical sequences are well developed in Western Australia. The most complete sequence of faunas is to be found in the onshore Carnarvon Basin (including the Merlinleigh and Byro Sub-basins; Figs 1, 2). Faunal zonation of the Early Permian (Archbold 1998a) is accompanied by detailed palynological biostratigraphy (Mory & Backhouse 1997). The Permian of the Carnarvon Basin was first recorded by Gregory (1861) and the first brachiopod fossils were described by Foord (1890). Much of Foord's material, collected by Mr Harry Page Woodward, then Western Australian Government Geologist, appears to have come from one of the most fossiliferous of the Early Permian units specifically the Callytharra Formation. The present report adds to those records or provides new morphological data on species previously described.

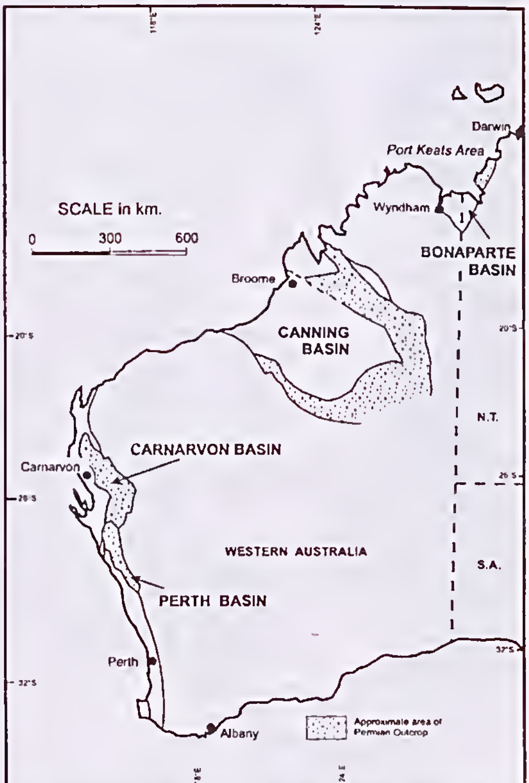

Fig. 1. Map of areas of outcrop of Permian strata in Western Australia.

STRATIGRAPHY AND AGE

The stratigraphy of the Permian sequences of the Carnarvon Basin has been described by Condon (1967) and Hocking et al. (1987). Condon (1967: 64–74) provided details of the type section of the Callytharra Formation (about 101 m thick, located about 110 km west of Callytharra Springs, adjacent to the Wooramel River; see Fig. 3 herein) and 12 reference sections—10 based on outcrops, 2 based on bore cores—measured at localities along the

390 km extent of outcrop of the unit (Fig. 4). Hocking et al. (1987: 76–80) noted that two broad facies occur within the Callytharra Formation—a fine grained facies which dominates the lower part of the Formation and a calcarenite facies, often strongly cemented, dominating the upper part. The latter facies is poorly developed in the region of the type section and this accounts for the excellent preservation of delicate fossils from the Wooramel River Area, such as those illustrated herein.

On the basis of interpretations of subsurface stratigraphy of bore cores, modifications to the understanding of the Callytharra Formation have been proposed by Mory (1996) and Mory & Backhouse (1997). These modifications essentially effect the upper parts of the formation as now defined in terms of quartz sandstone members and upward extentions of the definition of the unit to include the Jimba Jimba Calcarenite. The Callytharra Formation, as defined by these authors, includes, from the base, the palynomorph zones of *Pseudoreticulatispora pseudoreticulata*, *Striatopodocarpites fusus* and the base of the *Microbaculispora trisina* Zone (Mory & Backhouse 1997). In terms of brachiopod zones, the unit includes the *Strophalosia irwinensis* Zone followed by the *Strophalosia jimbaensis* Zone (Archbold 1993, 1998b). Based on the new definition of the Callytharra Formation, all material described and illustrated herein comes from the lower part of the Formation (ie. the unit in the sense of Condon 1967 and Hocking et al. 1987)—specifically the *Strophalosia irwinensis* Zone.

The age of the *Strophalosia irwinensis* brachiopod zone, in terms of the international subdivisions of the Permian Period, is best constrained by ammonoids that occur in the zone as part of the total fauna. The ammonoids (see Leonova 1998

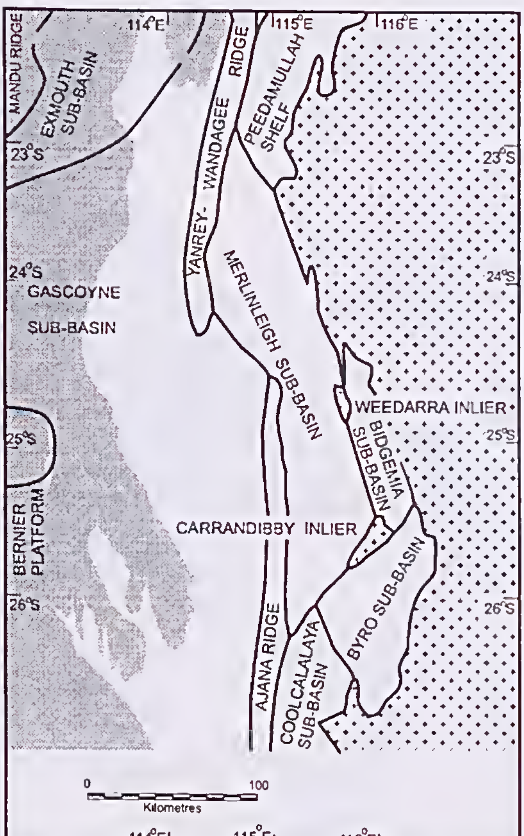

Fig. 2. Structural subdivisions of the Carnarvon Basin, Western Australia.

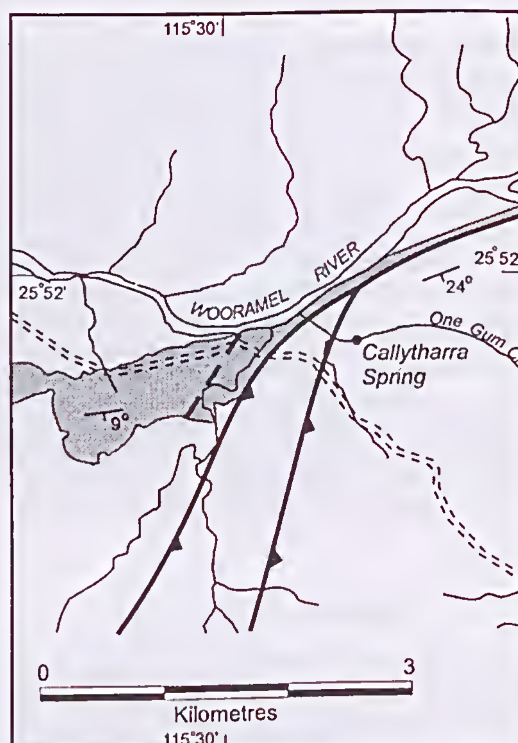

Fig. 3. Outcrop of the Callytharra Formation near Callytharra Springs. Condon's (1967) measured type section indicated by thick dashed line. Faults indicated by thick solid lines. Road indicated by double dashed line.

and Archbold 1998a) indicate a Sakmarian age and more specifically point to a Late Sakmarian (Sterlitamakian) age. The upper part of the Callytharra Formation (as defined by Mory & Backhouse 1997) appears to extend into the Artinskian (Aktastinian) as indicated by Archbold (1993) and Archbold & Shi (1993) and includes the *Strophalosia jimbaensis* brachiopod zone.

MATERIAL AND LOCALITIES

All specimens described and illustrated herein are derived from the region of the type section of the Callytharra Formation near the Wooramel River and were collected by Drs Arthur Mory and John Backhouse of the Geological Survey of Western Australia. Specimens are registered and housed with the Geological Survey of Western Australia, Perth (GSWA). Preservation of material is as original calcite shells with some crushing of the more delicate specimens.

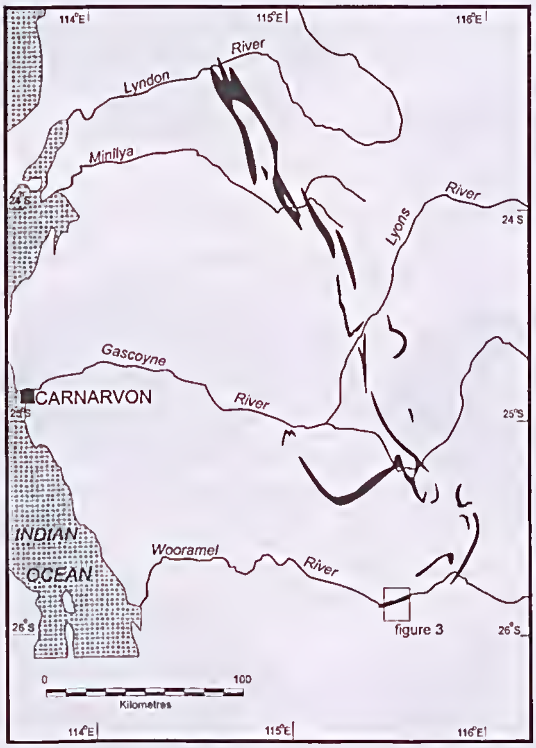

Fig. 4. Outcrop distribution of the Callytharra Formation in the Carnarvon Basin (shown in black).

Specific localities are:

GSWA Locality 144110 (AMG East 349480, AMG North 7137030), near Callytharra Springs, from second gully south of track, type section of Callytharra Formation. (Specimens GSWA F51004, 51007–51012, 51014–51015.)

GSWA Locality 144111, as for 144110, from fourth gully south of track. (Specimens GSWA F51005–51006, 51013.)

GSWA general locality, base of type section, weathered and loose surface material. (Specimens GSWA F51003.)

BRACHIOPOD FAUNA OF THE *STROPHALOSIA IRWINENSIS* ZONE, CALLYTHARRA FORMATION

As presently defined, the *Strophalosia irwinensis* Zone of the Callytharra Formation, Carnarvon Basin, is characterised by the most diverse assemblage of brachiopods of any zone of the Western Australian marine Permian sequences. Over 40 species have been documented and several additional, rare species await description. The following species are known from the Callytharra Formation. The list includes the new records described herein: *Permorthotetes callytharrensis* Thomas, *Permorthotetes camerata* Thomas, *Arctitreta plicatilis* (Hosking), *Tornquistia occidentalis* Archbold, *Tornquistia* cf. *subquadratus* Archbold, *Neochonetes (Sommeriella) prattii* (Davidson), *Strophalosia irwinensis* Coleman, *Etherilosia etheridgei* (Prendergast), *Aulosteges baracoodensis* Etheridge, *Aulosteges spinosus* Hosking, *Taeniothaerus irwinensis* Coleman, *Wooramella senticosa* (Hosking), *Comuquia australis* Archbold, *Lethamia? obscurus* Archbold, *Dyscrestia micracantha* (Hosking), *Callytharrella callytharrensis* (Prendergast), *Costatumulus irwinensis* (Archbold), *Globiella foordi* (Etheridge), *Camerisma callytharrensis* (Hosking), *Stenoscisma* sp. nov., *Myodelthyrium dickinsi* (Thomas), *Cyrtella?* sp., *Neospirifer (Quadrospira) hardmani* (Foord), *Neospirifer (Neospirifer) foordi* Archbold & Thomas, *Neospirifer (Quadrospira) preplicatus* Hogeboom, *Neospirifer* sp., *Latispirifer callytharrensis* Archbold & Thomas, *Trigonotreta neoaustralis* Archbold & Thomas, *Crassispirifer* sp., *Imperiospira dickinsi* Archbold & Thomas, *Elivina hoskingae* Archbold & Thomas, *Spirelytha fredericksi* Archbold & Thomas, *Phricodothyris occidentalis* Archbold & Thomas, *Tomiopsis woodwardi* Archbold & Thomas, *Tomiopsis* sp., *Fredericksia?* sp. nov., *Gjelispinifera decipiens* (Hosking), *Lamnaespina papilionata* (Hosking), *Callispirina* sp. nov., *Hustedia* sp. nov., *Cleiothyridina baracoodensis* Etheridge and *Fletcherithyris* sp. cf. *F. hardmani* Campbell.

At present, 19 of the above species (all known from the lower Callytharra Formation) are known from the correlative Fossil Cliff Formation of the Perth Basin (Archbold 1998b: 90). The *Strophalosia irwinensis* Zone is also recognised in the Canning Basin but 3 additional species, not known further south, are present in the assemblages, ie. *Permorthotetes lindneri* Thomas, *Cyrtella koopi* Archbold and *Cratispirifer nuraensis* Archbold & Thomas.

SYSTEMATIC PALAEONTOLOGY

Order CHONETIDA Nalivkin, 1979

Suborder CHONETIDINA Muir-Wood, 1955

Superfamily CHONETOIDEA Bronn, 1862

Family ANOPLIIDAE Muir-Wood, 1962

Subfamily ANOPLIINAE Muir-Wood, 1962

Genus Tornquistia Paeckelmann, 1930

Type species. *Leptaena (Chonetes) polita* McCoy, 1852.

Tornquistia sp. cf. *T. subquadratus* Archbold, 1990

Fig. 5A–C

Material. GSWA F51003, a complete conjoined shell from weathered, loose surface material from the base of the type section of the Callytharra Formation.

Measurements. Maximum width (hinge width) = 9.7 mm; height of ventral valve = 7.1 mm; height of dorsal valve = 5.9 mm; height of ventral interarea = 0.6 mm; height of dorsal interarea = 0.5 mm; shell thickness = 3.8 mm.

Comments. This single, well preserved specimen is placed on record and illustrated in view of its subquadrate outline and strongly convex ventral valve. The convexity of the ventral valve is evenly arched across the lateral valve flanks and hence is distinct from the ventral convexity of *Tornquistia occidentalis* Archbold (1980: pl. 25, figs 1b, 1c, 4b). *Tornquistia subquadratus* Archbold (1990) from the Sterlitamakian Cuneudgerie Sandstone of the Canning Basin possesses a more evenly convex ventral valve like that of the present specimen. Interior details are not known for this specimen.

Order PRODUCTIDA Sarycheva & Sokolskaya, 1959

Suborder PRODUCTIDINA Waagen, 1883

Superfamily AULOSTEGOIDEA Muir-Wood & Cooper, 1960

Family AULOSTEGIDAE Muir-Wood & Cooper, 1960

Subfamily AULOSTEGINAE Muir-Wood & Cooper, 1960

Genus Taeniothaerus Whitehouse, 1928

Type species. *Productus subquadratus* Morris, 1845.

Comments. Recent reviews of the type species and scope of the genus have been provided by Parfrey (1983) and Briggs (1998) and are accepted herein. *Taeniothaerus irwinensis* Coleman (1957) is unusual for the genus in view of its very low and narrow ventral interarea and the virtual absence or minor development of the cicatrix of attachment.

Taeniothaerus irwinensis Coleman, 1957

Fig. 5D–F

Taeniothaerus cf. *irwinensis*—Archbold 1990: 7, figs 3D–H, 4A–E.

Taeniothaerus irwinensis—Archbold et al. 1993: microfiche p. 46, pl. 30, figs 3, 5, 6, 9. (*cum. syn.*)

Comments. The occurrence of this species in the Callytharra fauna could not be confirmed by the survey of collections for the review by Archbold et al. (1993). The newly discovered specimen of an incomplete ventral valve (GSWA F51004), however leaves no doubt as to the species' presence in the fauna. The specimen possesses the characteristic ventral spine type and pattern, the weakly developed sulcus and the distinctive low ventral interarea (1.2 mm). The umbo is rounded, incurved and the ventral cicatrix of attachment is absent.

Fig. 5. A–C, *Tornquistia* sp. cf. *T. subquadratus* Archbold, GSWA F51003, shell in dorsal, posterior and ventral views, × 4.5. D–F, *Taeniothaerus irwinensis* Coleman, GSWA F51004, incomplete ventral valve in external views, × 1.5 and × 1.0, and internal view, × 1.5. G–P, *Wooramella senticosa* (Hosking). G–K, GSWA F51005, shell in dorsal, ventral and anterior views, × 1.25, and ventral and dorsal views, × 1. L–P, GSWA F51006, shell in dorsal and ventral views and anterior view, × 1.5 and × 1.0.


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Superfamily PRODUCTELLOIDEA
Schuchert & Le Vene, 1929

Family OVERTONIIDAE
Muir-Wood & Cooper, 1960

Subfamily TUBERSULCULINAE
Waterhouse, 1971

Genus Wooramella Archbold gen. nov.

Type species. *Pustula senticosa* Hosking, 1933, from the area of the type section of the Callytharra Formation, near Callytharra Springs, Wooramel River area.

Diagnosis. Concavo-convex shells with ornament of relatively coarse spines in concentric rows. Spine ridges imparting a coarse, costate appearance to ventral valve anteriorly at maturity, not developed posteriorly or over visceral disk. Spines absent on ears. Concentric growth lines present, diverging from umbones close to hinge line. Cardinal process low, bilobed. Dorsal septum short, thin. Ventral interior unknown.

Discussion. The rare type species of this new genus was compared with and assigned to *Stictozoster* by Grant (1976: 12) and Archbold (1984: 83) and assigned to *Lethamia* by Waterhouse (1981: 74). Waterhouse subsequently (1986: 36) questioned the assignment of the species to *Stictozoster*, noticing the coarser spines and that 'the critical details of the interior remain somewhat obscure'. The discovery of two additional specimens of the type species from the same local area as the original type material increases the data on the exterior morphology of the species and indicates that it belongs to a distinctive new genus.

Stictozoster was proposed by Grant (1976) for a strongly concavo-convex relatively small species, *S. leptus* Grant, from the mid-Permian (Ufimian) Rat Buri Limestone of Peninsular Thailand (see Archbold 1999 for a discussion of recent ideas on the age of the Rat Buri Limestone). *Stictozoster leptus* possesses fine spines that are closely spaced, and arranged in closely spaced concentric rows. The dorsal interior possesses a thin, delicate median septum and a small bilobed cardinal process. On the basis of the similar dorsal internal structures, Archbold (1984) assigned *Pustula senticosa* Hosking to *Stictozoster* while noting that 'the main difficulty in assigning (the species) to *Stictozoster* is the ornament of external coarse spines'. The coarser spines of Hosking's species were also noted by Waterhouse (1981: 74). Other species and records, based on external shell details, that are referred to *Stictozoster* include: *Productus licharewi* Frebold (1942: 38, pl. 3, figs 7–9) from the mid-Permian Productus Limestone of Kap Stosch, Greenland, and its probable junior synonym *Krotovia nielseni* Dunbar (1955: 84, pl. 8, figs 1–6) from the same locality and horizon; *Krotovia licharewi* of Gobbett (1964: 59, pl. 3, figs 1–10) from younger mid-Permian beds of the Middle Brachiopod Chert, Spitzbergen; *Stictozoster* cf. *S. leptus* of Archbold (1981: 10, pl. 1, figs 10, 14, 15) from the Ufimian Aifat Formation of Irian Jaya; *Stictozoster?* sp. Waterhouse (1981: 74, pl. 8, fig. 2) from the possible Artinskian Ko Yao Noi Formation, Peninsular Thailand; *Stictozoster* sp. Archbold (1992: 294, fig. 5L) from the Artinskian Aiduna Formation, Irian Jaya; *Stictozoster lata* Shi & Waterhouse (1991: 28, figs 2–11, 12, 13, 15 *non cet.*) from the Late Sakmarian to early Artinskian Nam Loong Beds, Perak, Malaysia (other specimens figured as this species by Shi & Waterhouse [1991: figs 2–14, 17, 18] are excluded because they possess pronounced spine ridges); *Stictozoster* sp. Archbold & Barkham (1989: fig. 3D–E) from the Sterlitamakian Maubisse Formation of Bisnain, Timor; and both *Productus dussaulti* and *P. propinquus* Mansuy (1913: 34, pl. 2, figs 10, 11) from the Early Permian Productus Limestones of Kham-keut, Laos. Possibly allied are *Productus iakovlevi* Chernyshev (1902: 300, pl. 56, figs 17–19) from the Sakmarian of Mt Sik'-Takty, Russia; the *Productus iakovlevi laosensis* Mansuy (1913: 41, pl. 3, fig. 9) from the Early Permian of Kham-keut, Laos, and *Productella tenuispina* Mansuy (1912: 43, pl. 8, fig. 13a–b) from the Upper Permian of Ban Na-Hai, northern Laos, all forms with very fine spines.

The genus *Markamia* Jin & Shi 1985 (type species *Markamia transversa* Jin & Shi 1985, in Jin et al. 1985: 192, pl. 11, figs 2, 3), from the Lizha Formation of Markham County, East Qinghai-Xizang Plateau, is of Late Carboniferous to Earliest Permian age. It is a form close to *Stictozoster*, with a rounded outline and fine spines in concentric rows and is allied to the *Productus iakovlevi* Chernyshev group of species.

All of the above reports represent species that possess growth lines that converge towards the umbones at the hinge line, very fine body spines arranged in distinct concentric rows and also present on the small ears and lack the development of coarse spine ridges anteriorly at maturity.

A relatively similar genus to *Wooramella* is *Lethamia* Waterhouse (1973: 38, figs 2–4, 5) with several species well described by Waterhouse (1982, 1986) and Briggs (1998) from Artinskian to Midian strata of eastern Australia and New Zealand.

Lethamia is distinguished from *Wooramella* by its finer spines, which are 'dense on ears' (Waterhouse 1973: 38, 1982: 42), growth lines that normally converge towards the umbones at the hinge line (imparting a rounded outline to the shell) and lack of spine ridges anteriorly at maturity. Contrary to the statement by Waterhouse (1986: 35) that Archbold (1984) had 'misrepresented the dorsal median septum of *Lethamia* as being always massive and raised anteriorly', nowhere did Archbold describe it as massive and his text makes it clear that he was discussing mature specimens in his comparisons. No juvenile shells were described by Waterhouse (1973, 1982) and he stated unambiguously that the dorsal median septum increased 'anteriorly in width and height' (op. cit., 1973: 40, 1982: 43) and hence is quite unlike that of mature *Wooramella senticosa* (see Archbold 1984: fig. 1D–E). It is to be expected that juvenile *Lethamia* would possess a much more delicate structure but this was not figured by Waterhouse (cf. Waterhouse 1982: pl. 9, figs F, I).

The Queensland Artinskian species *Lethamia rara* Briggs (1998: 127, fig. 65A–F) is of note as the only species of the genus that is widest at the hinge indicating a weakly developed divergence of growth stages away from the umbones at the hinge line. However, spines are more concentrated and slightly coarser on the ears unlike those of *Wooramella* which are absent on the ears and spines are somewhat scattered over the ventral valve.

A non Gondwanan species that may be allied to *Wooramella* is *Productus pustulatus* von Keyserling (1853: 247), a species figured by Grünewaldt (1860: 127, pl. 3, fig. 3) and Chernyshev (1902: 271, pl. 30, figs 1, 2; pl. 51, figs 5, 6) from the Sakmarian of the Urals that possess relatively coarse spines, at times absent on ears (cf. Chernyshev 1902: pl. 53, fig. 5b; pl. 30, fig. 1a–b) and growth lines that diverge from the umbones close to the hinge line (Chernyshev 1902: pl. 30, fig. 2c). Subsequent records of the species vary in other details. Reports of the species from the Early Permian of the Taimyr Peninsular (Einor 1946: 32, pl. 5, figs 3–6; Ustritskiy & Chernyak 1963: 74, pl. 4, figs 5–6) are of small specimens with coarse spines and less transverse outline. Gzhelian records from Bashkiria are of specimens with fine spines on the ears (Stepanov 1948: 28, pl. 5, fig. 6) or with no ear spines and growth lines that deflect outwards at the hinge (Mironova 1967: 14, pl. 1, figs 16, 17). Sarycheva & Sokolskaya (1952: pl. 14, fig. 100) figured a Gzhelian specimen with coarse spines arranged in quinqunx but absent over the ears. *Productus (Avonia) pustulatus* var. *stepanovi* Kulikov (1939: 160, pl. 2, fig. 4) from the Sakmarian of the southern Urals is a form with coarse spines, apparently absent from the ears, and appears closer to Chernyshev's (1902) material. The Chinese record of the species (Chao 1928: 52, pl. 5, figs 18–20) is a Late Carboniferous form of moderate size and distinct ear spines.

Wooramella senticosa (Hosking, 1933)

Fig. 5G–P

Stictozoster senticosa—Archbold, 1984: 83, fig. 1A–H (*cum. syn.*)—Archbold et al., 1993: microfiche 52, pl. 33, figs 1–3.—Archbold & Shi, 1995: figs 5–8, 9.

Material. Two somewhat crushed but complete shells (GSWA F51005–51006) from GSWA Locality 144111, Callytharra Formation type section.

Comments. The syntypic series of three specimens has been described and figured by Hosking (1933: 47, pl. 3, figs 2–3), Coleman (1957: 63, pl. 7, figs 11–15) and Archbold (1984: 83, fig. 1A–H). The new material provides data on the true nature of the growth lines diverging from the umbones close to the hinge line and the formation of a smooth area of the ears with an absence of spines on the ears of both valves. This posteriorly developed smooth region coincides with the region where the growth lines diverge. The specimens of the syntypic series all possessed damaged ears (as, to some extent, the new specimens) and hence this distinctive feature is not apparent but it is well shown by GSWA F51005 (Fig. 5G–K herein). The new material (GSWA F51006) also shows the variable development of prominent spine ridges on the external ventral trail at maturity. The new specimens do not add to the knowledge of the shell interior.

Superfamily PRODUCTOIDEA Gray, 1840

Family DICTYOCLOSTIDAE Stehli, 1954

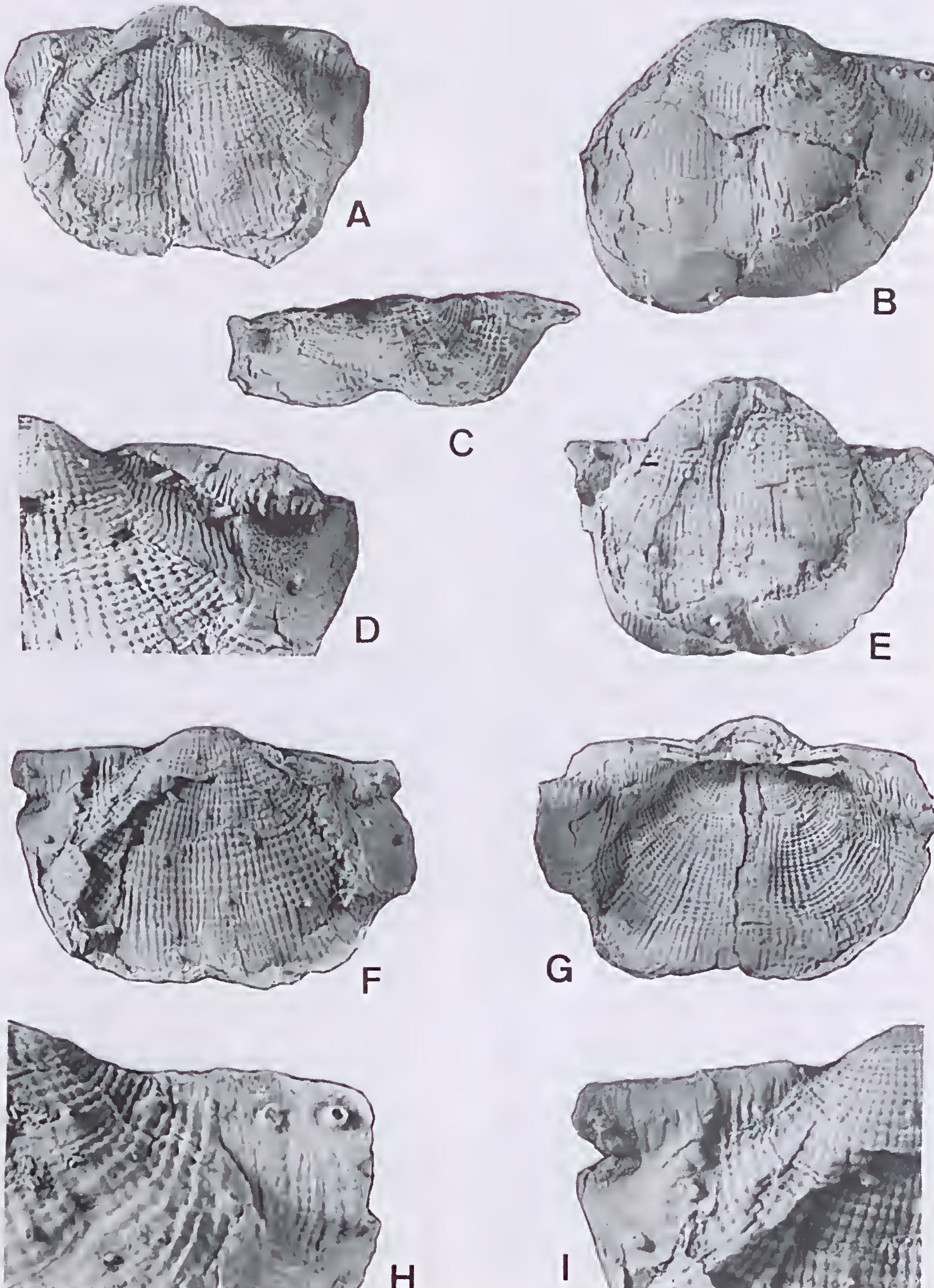
Subfamily DICTYOCLOSTINAE Stehli, 1954

Genus Callytharrella Archbold, 1985

Type species. Dictyoclostus callytharrensis Prendergast, 1943.

Callytharrella callytharrensis (Prendergast, 1943)

Figs 6A–I, 7A–E



Callytharrella callytharrensis—Archbold, 1985: 19, figs 1A–T, 2A–F, 3A–H (*cum. syn.*).—Archbold et al., 1993: microfiche 58, pl. 34, figs 1–5 (*cum. syn.*).—Archbold & Shi, 1993: 189, fig. 3N–O.—Archbold & Shi, 1995: 210, figs 5–20, 21.

Material. A well preserved, though crushed suite of six specimens (GSWA F51007–51012) from GSWA Locality 144110, Callytharra Formation, type section.

Comments. Although this species has been rather fully described by Prendergast (1943), Coleman (1957) and Archbold (1985), the new material provides significant additional data on the nature of the ears and the development of the spines and costae associated with them. The ears of mature specimens are often damaged or broken off completely during preservation or collecting (eg. Fig. 7C herein). The new material also demonstrates the pattern of widely spaced dimples (corresponding to spines on the ventral valve) on the dorsal valve exterior (Figs 6G, 7D herein).

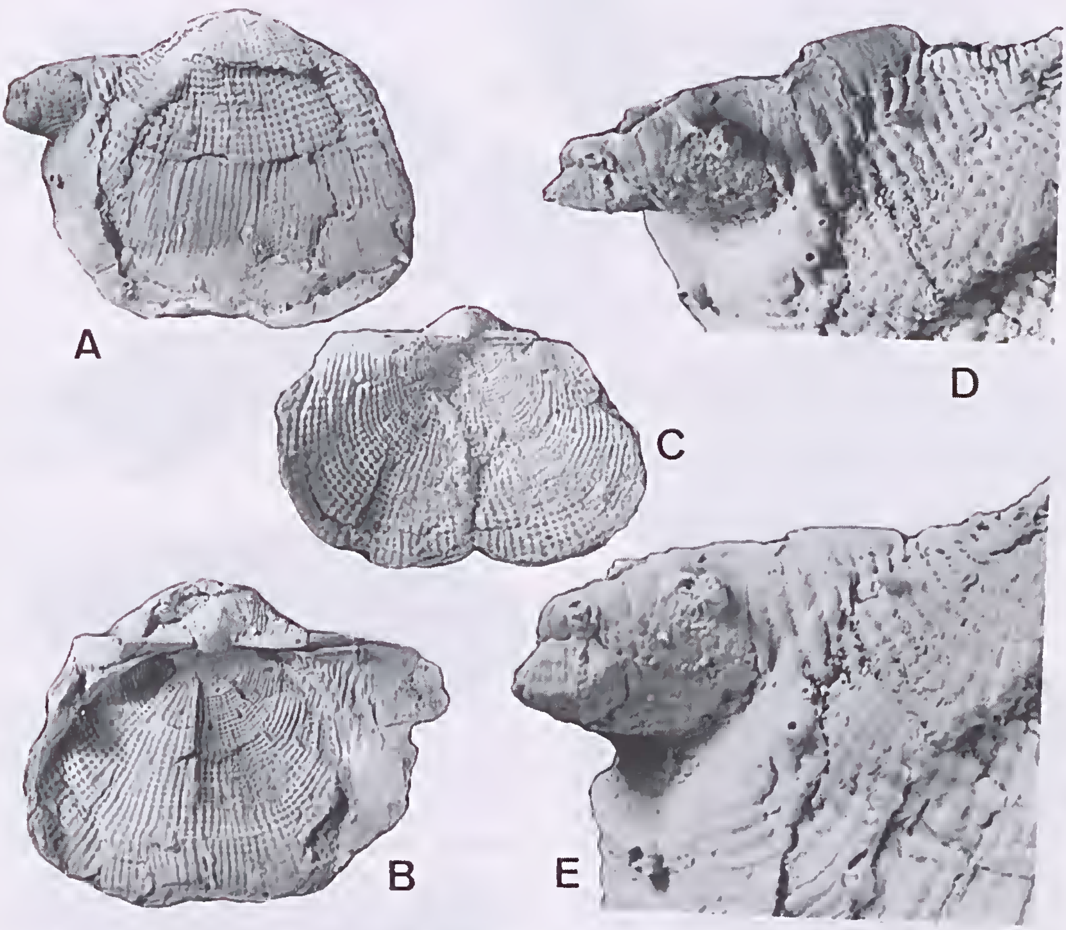


Fig. 7. A–E, *Callytharrella callytharrensis* (Prendergast). A, B, D, E, GSWA F51011, shell in ventral and dorsal views, ×1, and ear in two views, ×4. C, GSWA F51012, shell in dorsal view, ×1.

Fig. 6. A–I, *Callytharrella callytharrensis* (Prendergast). A, D, GSWA F51007, shell in ventral view, ×1 and ear enlarged, ×2. B, C, H, GSWA F51008, shell in ventral and posterior views, ×1, ear enlarged, ×2. E, GSWA F51009, shell in ventral view, ×1. F, G, I, GSWA F51010, shell in ventral and dorsal views, ×1, ear enlarged, ×2.

Coleman (1957: 55) noted that the ears 'are large and reflexed, separated from the body of the shell by a fold bearing a row of spines (3–4) of large size', as indicated by one of his illustrated specimens (op. cit., pl. 6, fig. 8, left ear). This feature, not evident on the specimens described by Archbold (1985), is shown by one of the new specimens (GSWA F51011; Fig. 7A, B, E, herein). During crushing, the ears tend to break at about the position of this fold (or 'crinkle') hence obscuring recognition of the feature. This 'crinkle' does not appear to develop on all specimens and hence is not a stable feature of the species. Spines are arranged along the 'crinkle' or in a position comparable to that of the 'crinkle', with the maximum number of spines being five but normally up to four. Costae develop on the lateral extensions of the ears at maturity and become more pronounced on gerontic individuals where they curve around the enrolled ears.

Order SPIRIFERIDA Waagen, 1883

Suborder SPIRIFERIDINA Waagen, 1883

Superfamily SPIRIFEROIDEA King, 1846

Family SPIRIFERIDAE King, 1846

Subfamily NEOSPIRIFERINAE Waterhouse, 1968

Genus Neospirifer Fredericks, 1923

Type species. *Spirifer fasciger* von Keyserling, 1846 from the Early Permian of the Soiva River, tributary of the Pechora River, south Timan.

Comments. Since the review of *Neospirifer* by Archbold & Thomas (1984), who figured excellent quality replicas of von Keyserling's syntypic series of *Spirifer fasciger*, the scope and definition of the genus have been considered recently by Abramov & Grigor'eva (1988), Poletaev (1997), Archbold (1997) and Kalashnikov (1998). Abramov & Grigor'eva (1988) reassigned numerous species, previously included within *Neospirifer*, to other related genera. Poletaev (1997) redescribed the syntypic series of *Spirifer fasciger* and tightened the diagnosis of *Neospirifer* to include only species with an acute crest to the dorsal fastigium. Species assigned by Poletaev (1997) to *Neospirifer* were severely reduced in number as were species referred to the genus by Kalashnikov (1998). Archbold (1997) suggested that the genus was broadly understood and that subgroupings of species could be recognised. As a result the subgenus *Neospirifer (Quadrospira)* was proposed and a range of Gondwanan species referred to the subgenus (Archbold 1997: 214). Specimens described herein are assigned to *Neospirifer (Quadrospira)* on the basis of the presence of attenuated ears and truncated interareas.

Subgenus Neospirifer (Quadrospira) Archbold, 1997

Type species. *Neospirifer plicatus* Archbold & Thomas, 1986 from the Baigendzhinian (Late Artinskian) Madeline Formation, Carnarvon Basin, Western Australia.

Neospirifer (Quadrospira) hardmani (Foord, 1890)

Fig. 8H–L

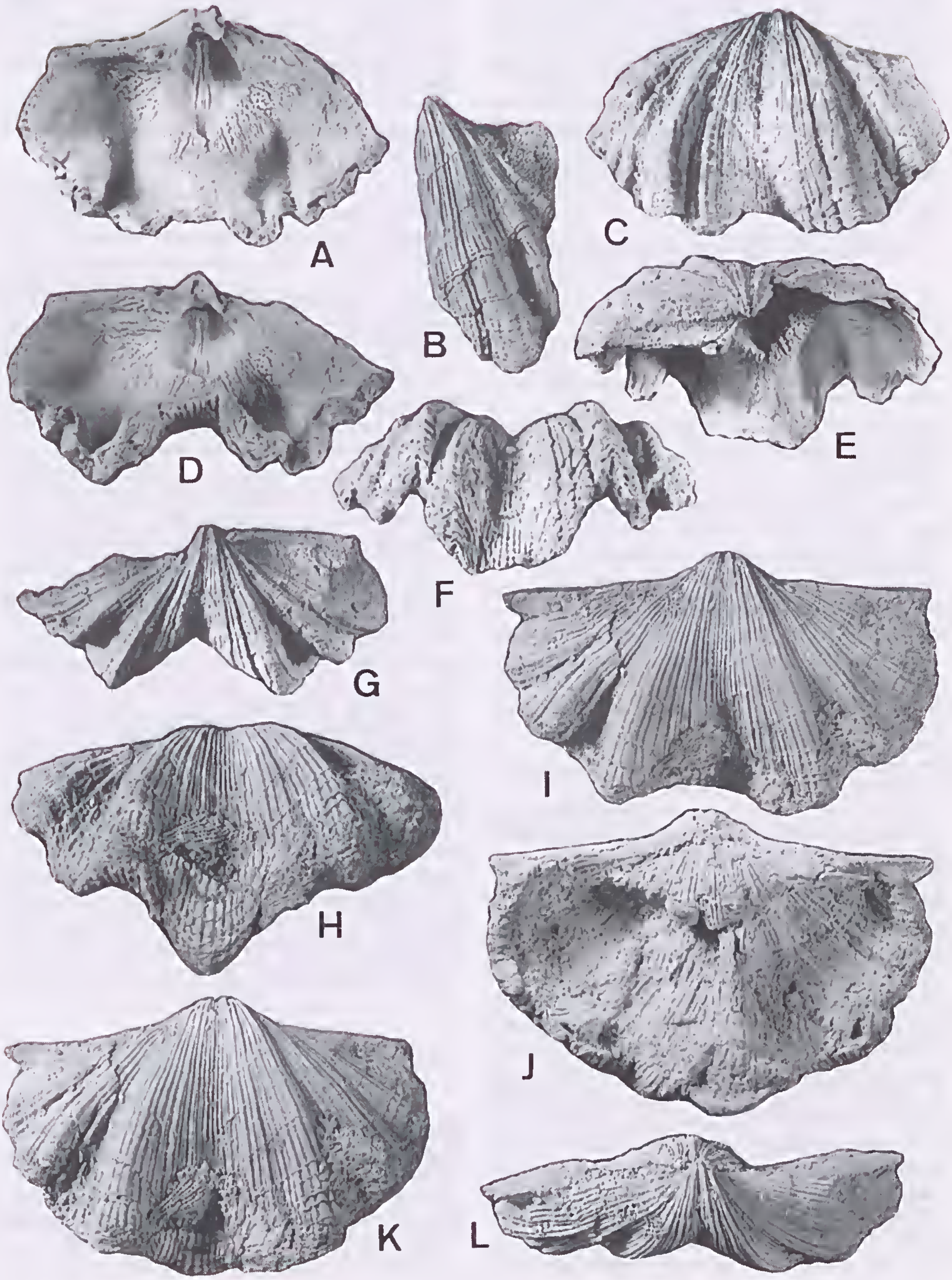
Neospirifer hardmani—Archbold & Thomas, 1986: 128, figs 1A–N, 2A–I, 3A–I (*cum. syn.*)—Archbold et al., 1993: microfiche 80, pl. 37, figs 3, 4, 6.—Archbold & Shi, 1993: 199, fig. 6C–E.—Archbold & Shi, 1995: 210, figs 4–5.

Material. A single specimen (GSWA F51013) of a shell with crushed dorsal valve from GSWA Locality 144111.

Measurements. Maximum width = 63.3 mm; hinge width = 61.5 mm; height of ventral valve = 42.0 mm; height of dorsal valve = 39 mm.

Comments. Archbold & Thomas (1986: 130) noted that the lateral plications of this species varied from being weakly to moderately strongly developed. We illustrate herein one of the specimens known to us that demonstrates very strongly developed lateral plications. Forms such as this are rare and represent an extreme variant of the species. Its importance lies in the fact that it serves as a useful comparison with the highly distinctive specimen described below as a new and very rare species.

Fig. 8. A–G, *Neospirifer (Quadrospira) preplicatus* Hogeboom. A, C–G, holotype, GSWA F51014, ventral valve in internal, external, posteriorly tilted, anteriorly tilted, anterior and posterior views, × 1, GSWA F51015, portion of ventral valve in ventral view, × 1. H–L, *Neospirifer (Quadrospira) hardmani* (Foord), GSWA F51013, shell in antero-ventral, postero-ventral, dorsal, ventral and posterior views, × 1.


A
B
C
D
E
F
G
H
I
J
K
L

Pertinent features of the specimen are its fine equidimensional costae increasing in numbers by bifurcation; three distinct pair of ventral lateral plications which are strongly developed and well rounded; feeble plications on the sulcal flanks; the gentle arching of the ventral valve imparting a flattish appearance and rounded growth lines on the sulcal tongue at juvenile and submature stages of growth. Other features of the specimen are as described for the species by Archbold & Thomas (1986).

Neospirifer (Quadrospira) preplicatus Hogeboom sp. nov.

Fig. 8A–G

Holotype. A ventral valve (GSWA F51014) from GSWA Locality 144110, type section of Callytharra Formation near Callytharra Springs, Wooramel River area, Carnarvon Basin, Western Australia.

Material. In addition to the holotype, a portion of a ventral valve (GSWA F51015) is provisionally assigned to the species.

Measurements of holotype. Maximum width = 53 mm; hinge width = 42 mm (estimate); height of ventral valve = 33 mm; height of ventral interarea = 4.5 mm.

Diagnosis. Medium sized *Neospirifer (Quadrospira).* Ventral lateral plications pronounced, narrow and sharp. Sulcus deep, u-shaped. Interplication valleys deep. Costae moderately coarse—finer in sulcus. Growth lamellae v-shaped in sulcus. Ventral valve strongly arched laterally. Shell extensively thickened with deep ventral interior.

Description. Moderate sized species, subquadrate at maturity. Ears attenuated at maturity.

Ventral umbo small, sharp, pointed, incurved, overhanging prominent interarea which is striated horizontally and bears several denticular grooves. Delthyrium prominent. Sulcus broad, deep, v-sided with u-shaped base. Sulcal tongue long. Sulcus arises at umbo, defined by inner pair of plications; these are rapidly incorporated into sulcus as well defined, sharp plications on the sulcal flanks; they are still prominent at valve anterior. Lateral plications consist of 3 pairs; they are pronounced, narrow and sharply defined. Interplication valleys deep. Costae moderately coarse—finer in sulcus; up to 2.0 mm wide on crest of sulcal bounding plications at anterior of valve and 1.0 mm wide in middle of sulcus at valve anterior. Costal interspaces narrow up to 0.5 mm wide at valve exterior.

Dental flanges stout, support robust teeth; adminicula well developed, buried in shell thickening. Ventral muscle field elongate, adductor scars prominently striated. Delthyrial plate small, apical callosity strengthens plate. Ventral interarea horizontally striated, denticular grooves weekly developed, sparse. Delthyrial ridge and groove distinct. Floor of ventral valve deep and extensively thickened including anterior.

Dorsal valve unknown.

Growth lamellae distinct, crowded together at valve anterior.

Discussion. The holotype of the species and the fragment of a second valve, possess such distinctive features of the lateral plications and arching of the ventral valve that they are precluded from inclusion within the broad definition of *N. (Q.) hardmani* (Foord, 1890). They are closest to *Neospirifer (Quadrospira) plicatus* Archbold & Thomas (1986) from the Artinskian Madeline Formation of the Carnarvon Basin but the latter species, despite possessing pronounced lateral plications possesses only a weakly developed third (outer) pair and the interplication valleys are broad and less well defined. *N. (Q.) postplicatus* Archbold & Thomas (1986) from the Kungurian Wandagee Formation and correlatives is a larger species with two pair of ventral lateral plications. The Early Artinskian *N. (Q.) woolagensis* Archbold (1997) from the High Cliff Sandstone, Perth Basin, possesses somewhat lower and less defined lateral plications and coarser costae. The Late Permian (Djhulfian) species from Tibet and Western Yunnan, *Neospirifer tibetensis* Ting (1962: 454, pl. 2, figs 4, 5; see also Yang & Zhang 1982: 312, pl. 3, figs 2–4) and *Neospirifer kubeiensis sensu* Fang (1995: 140, pl. 5, figs 10–12) are large species, presumably evolutionary descendants from the lineage of Western Australian Early Permian species. Fang (1995) considered that his material was of Early Permian age but the associated brachiopod fauna shares many features with those of Djhulfian assemblages of the Salt Range, Indian Himalaya, Nepal, and Western Australia (such as *Waagenites*, *Costiferina*, *Leptodus* and large athyrids) and hence a Late Permian age is preferred for the Yunnan fauna.

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